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(54) **SEWING MACHINE, COMPUTER-READABLE MEDIUM STORING SEWING PROGRAM, AND SEWING METHOD**

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D05B 19/08 (2006.01)
D05B 19/10 (2006.01)

(52) **U.S. Cl.**
CPC ***D05B 19/08*** (2013.01); ***D05B 19/10*** (2013.01)
USPC **700/138**; 112/470.01

(58) **Field of Classification Search**
USPC 700/136–138; 112/102.5, 470.01, 112/470.04, 470.06, 475.18, 475.19
See application file for complete search history.

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(57) **ABSTRACT**

The memory stores computer-readable instructions causing the sewing machine to perform operations including: extracting feature points of a design based on a captured image; extracting feature points of a unit design; generating feature points of a symmetrical design; cross-checking the extracted feature points of the design and the generated feature points of the symmetrical design; determining an arrangement of an embroidery pattern with respect to the symmetrical design; and causing a sewing portion to sew the embroidery pattern.

18 Claims, 13 Drawing Sheets

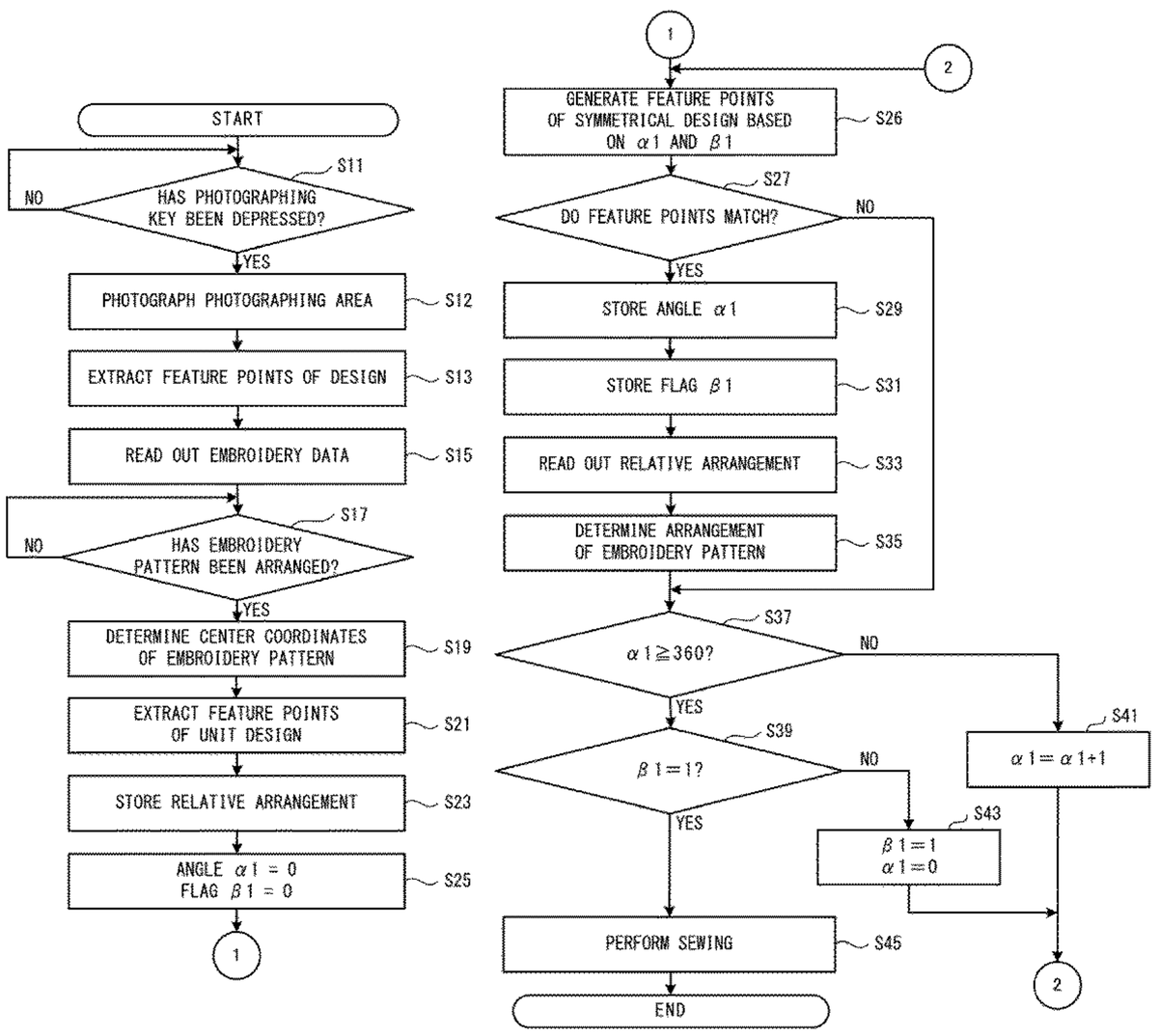


FIG. 1

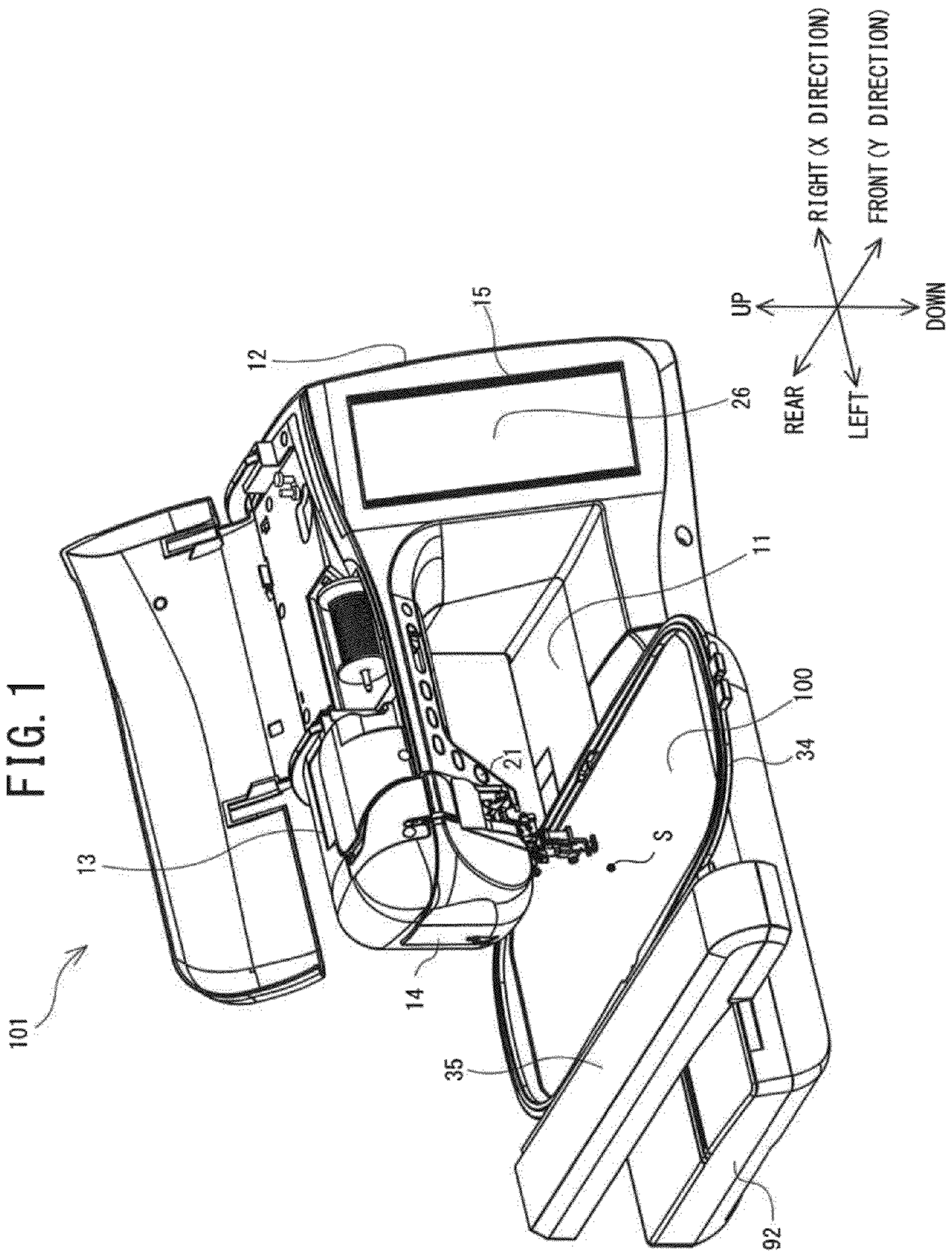

RIGHT (X DIRECTION)
FRONT (Y DIRECTION)
UP
DOWN
REAR
LEFT
101
12
15
26
11
100
34
21
13
S
14
35
92

FIG. 2

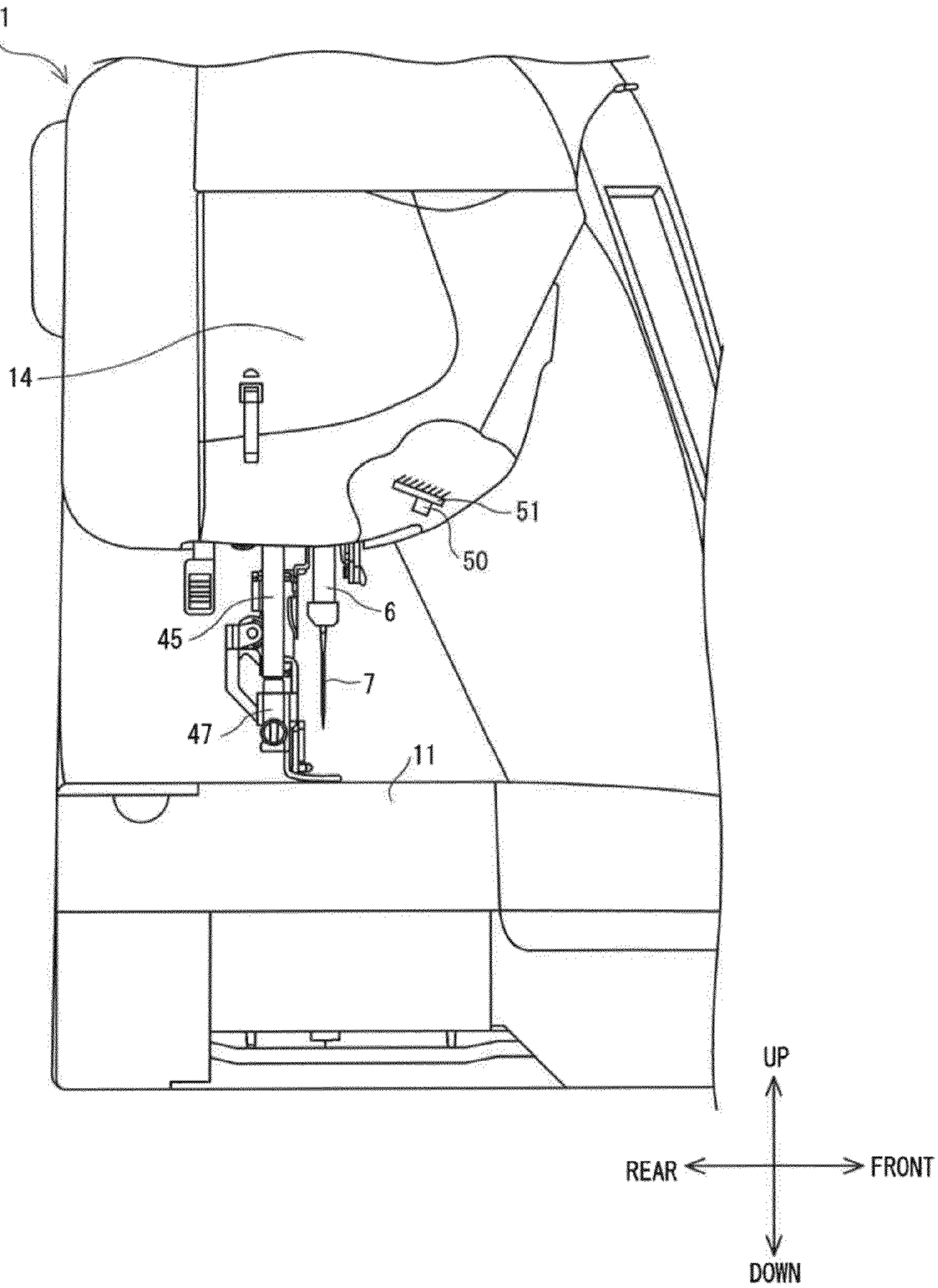


FIG. 3

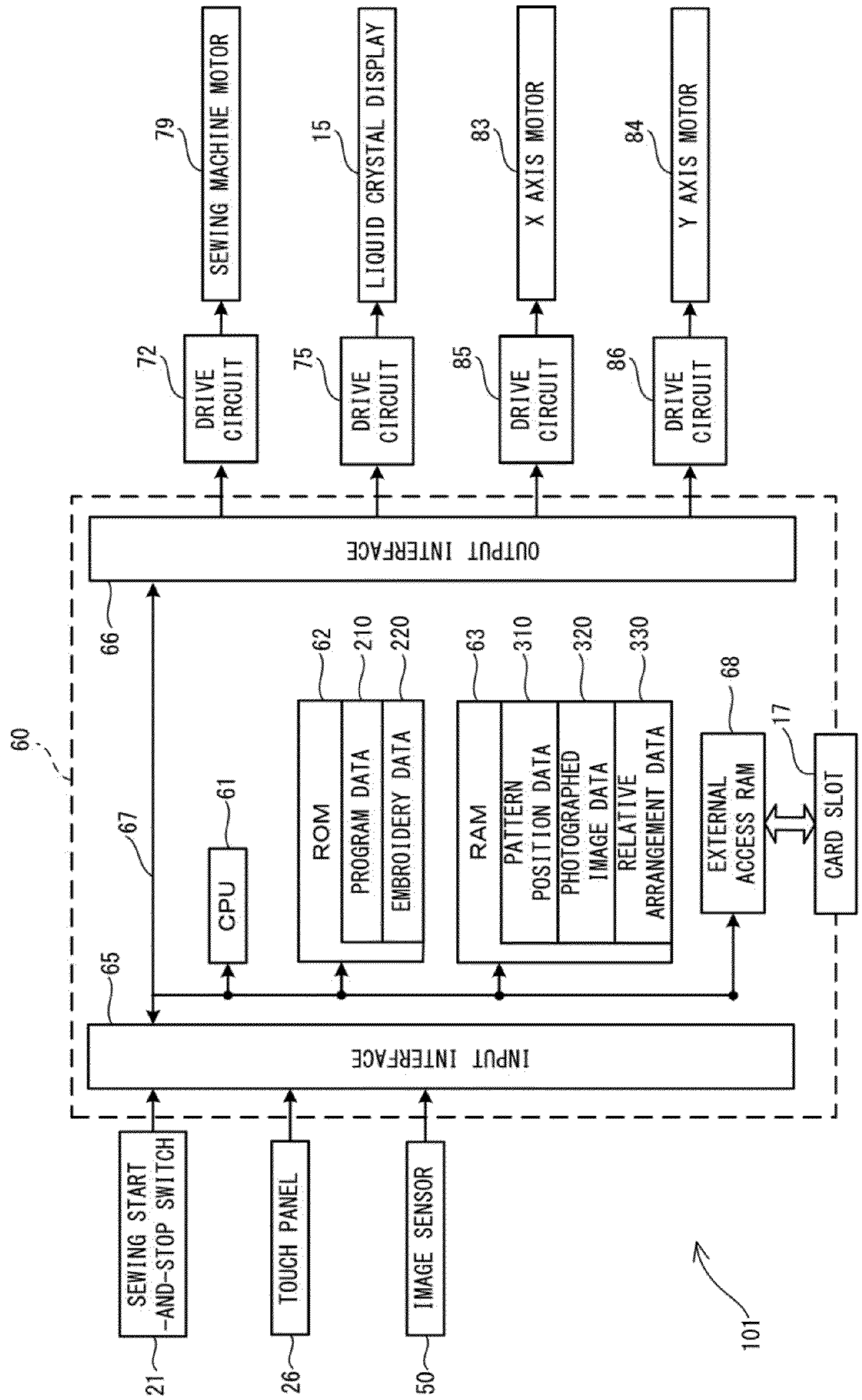

60
SEWING MACHINE MOTOR
79
LIQUID CRYSTAL DISPLAY
15
X AXIS MOTOR
83
Y AXIS MOTOR
84
DRIVE CIRCUIT
72
DRIVE CIRCUIT
75
DRIVE CIRCUIT
85
DRIVE CIRCUIT
86
OUTPUT INTERFACE
66
67
65
CPU
61
ROM
62
PROGRAM DATA
210
EMBROIDERY DATA
220
RAM
63
PATTERN POSITION DATA
310
PHOTOGRAPHED IMAGE DATA
320
RELATIVE ARRANGEMENT DATA
330
EXTERNAL ACCESS RAM
68
CARD SLOT
17
INPUT INTERFACE
SEWING START -AND-STOP SWITCH
21
TOUCH PANEL
26
IMAGE SENSOR
50
101

FIG. 4

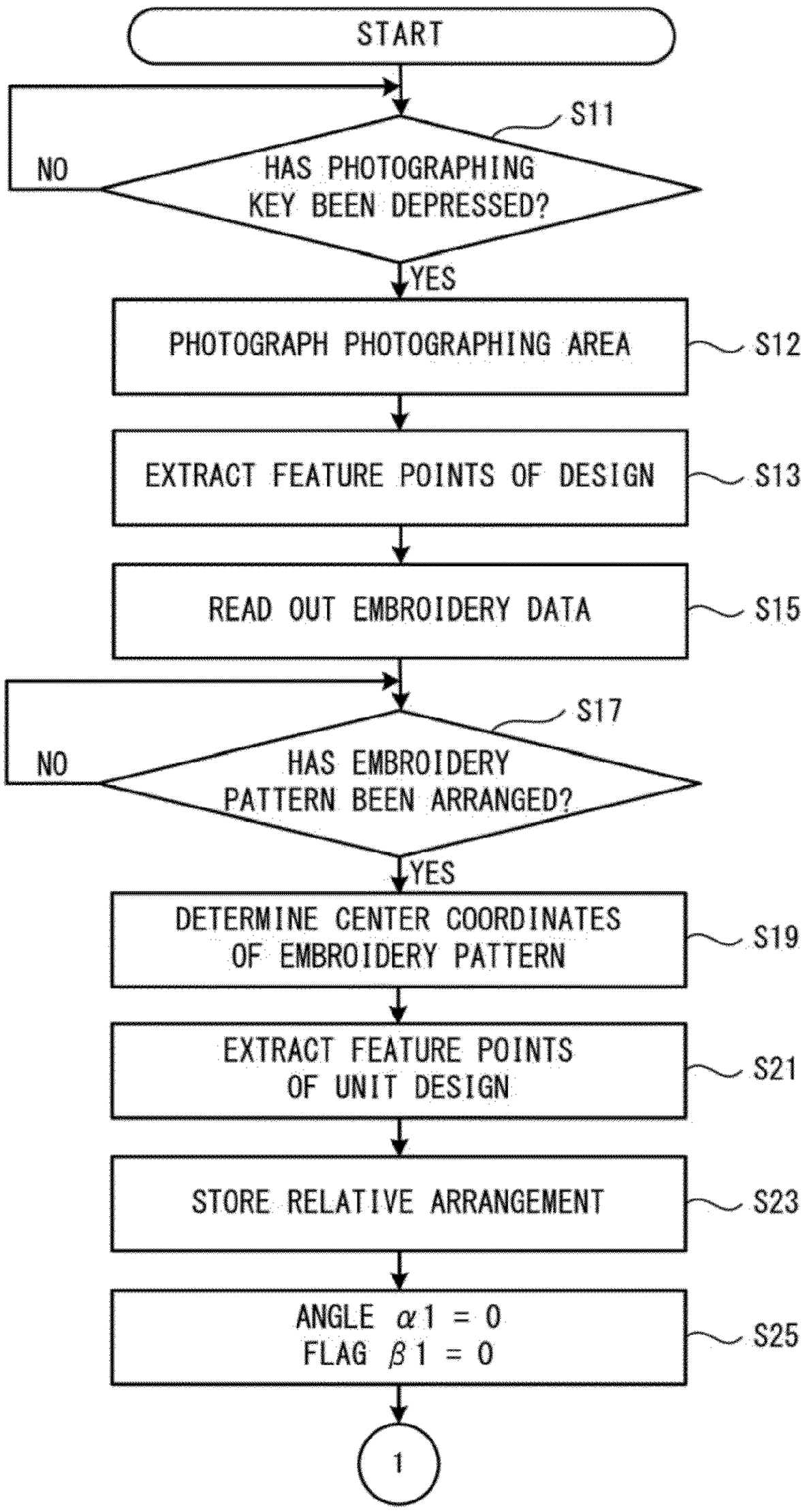

START
S11
NO
HAS PHOTOGRAPHING KEY BEEN DEPRESSED?
YES
PHOTOGRAPH PHOTOGRAPHING AREA
S12
EXTRACT FEATURE POINTS OF DESIGN
S13
READ OUT EMBROIDERY DATA
S15
S17
NO
HAS EMBROIDERY PATTERN BEEN ARRANGED?
YES
DETERMINE CENTER COORDINATES OF EMBROIDERY PATTERN
S19
EXTRACT FEATURE POINTS OF UNIT DESIGN
S21
STORE RELATIVE ARRANGEMENT
S23
ANGLE α1 = 0
FLAG β1 = 0
S25
1

FIG. 5

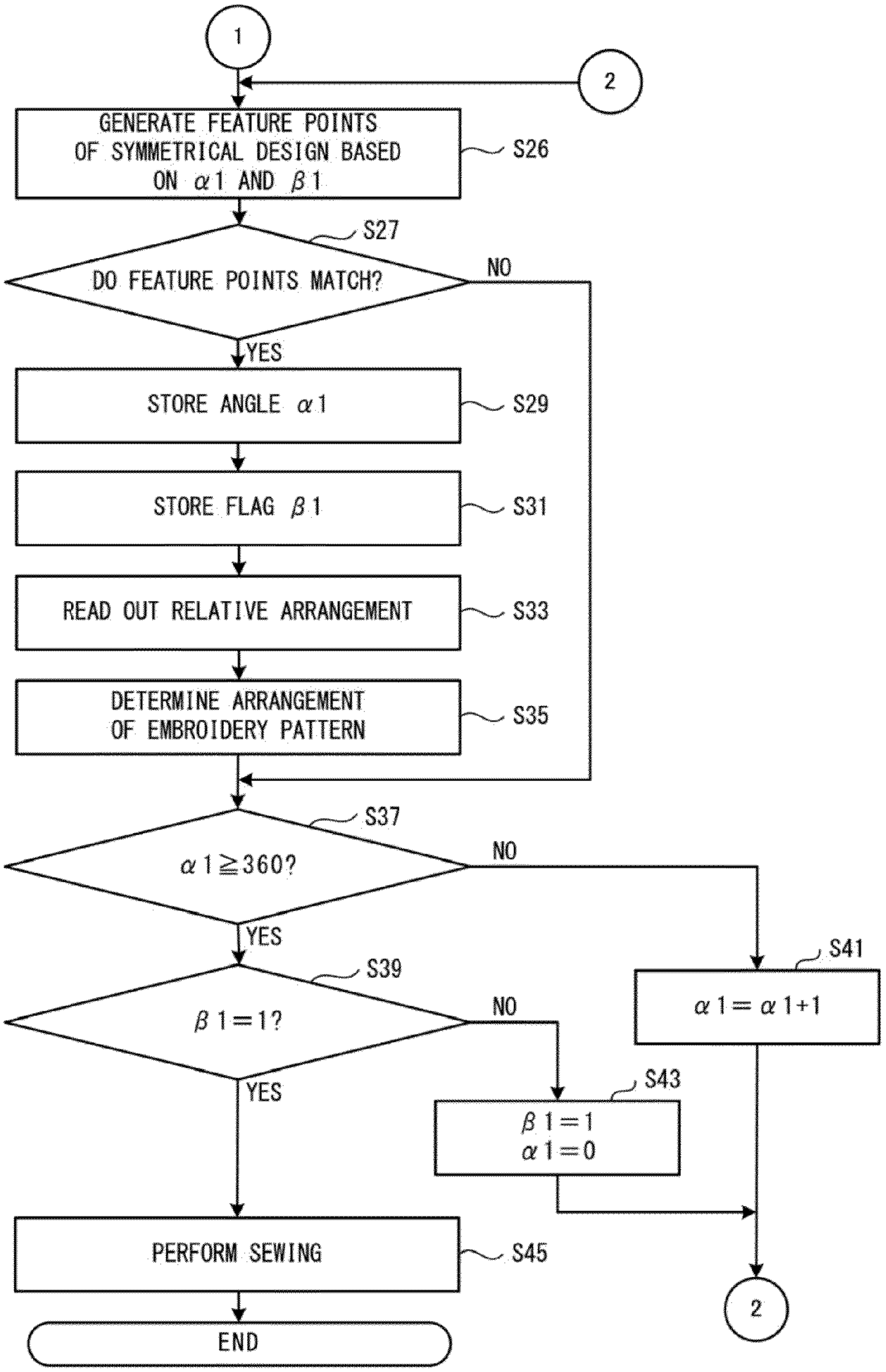

1
2
GENERATE FEATURE POINTS OF SYMMETRICAL DESIGN BASED ON α1 AND β1
S26
S27
DO FEATURE POINTS MATCH?
NO
YES
STORE ANGLE α1
S29
STORE FLAG β1
S31
READ OUT RELATIVE ARRANGEMENT
S33
DETERMINE ARRANGEMENT OF EMBROIDERY PATTERN
S35
S37
α1≧360?
NO
YES
S39
β1=1?
NO
YES
S41
α1=α1+1
S43
β1=1
α1=0
PERFORM SEWING
S45
END
2

FIG. 6

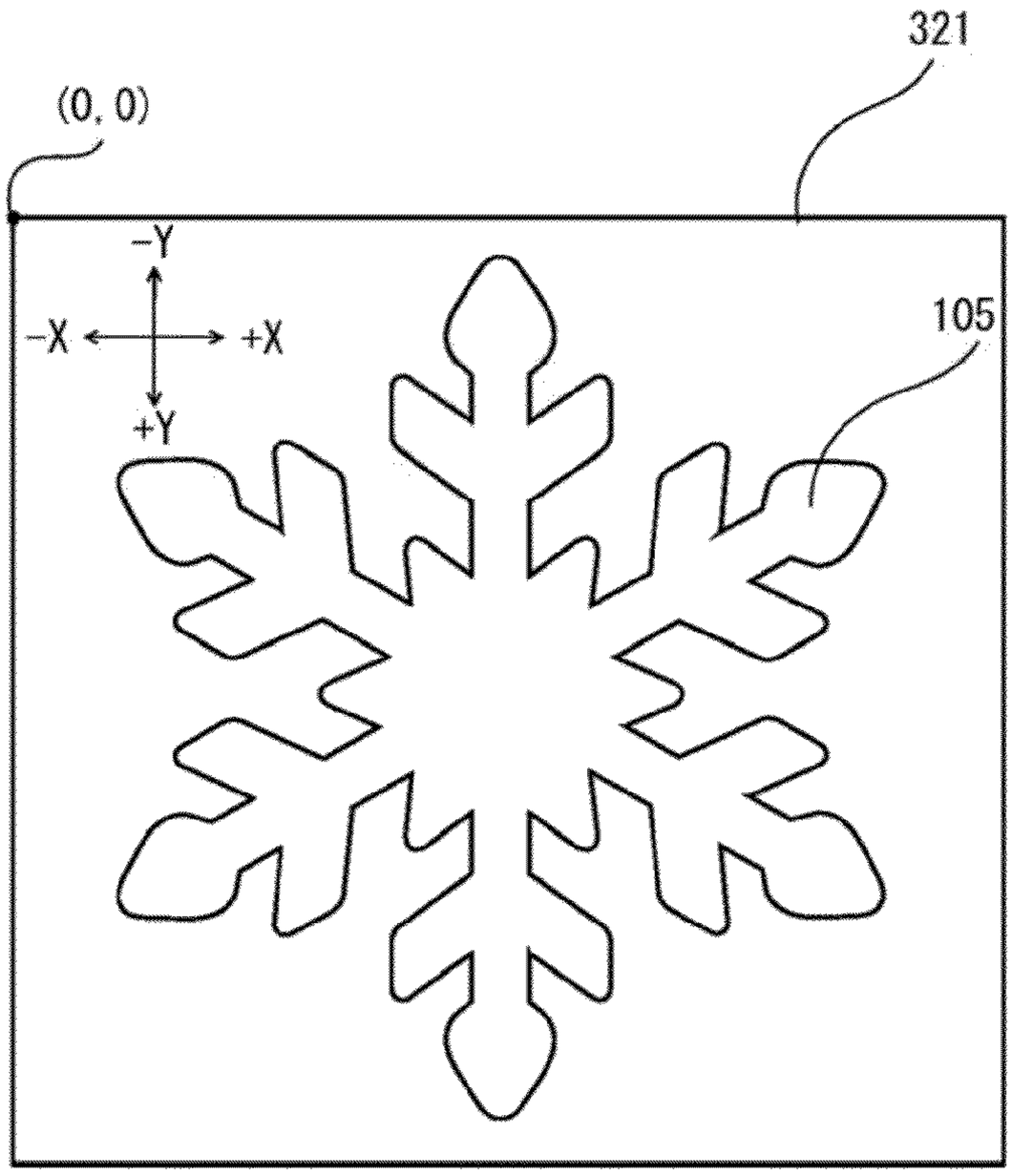


FIG. 7

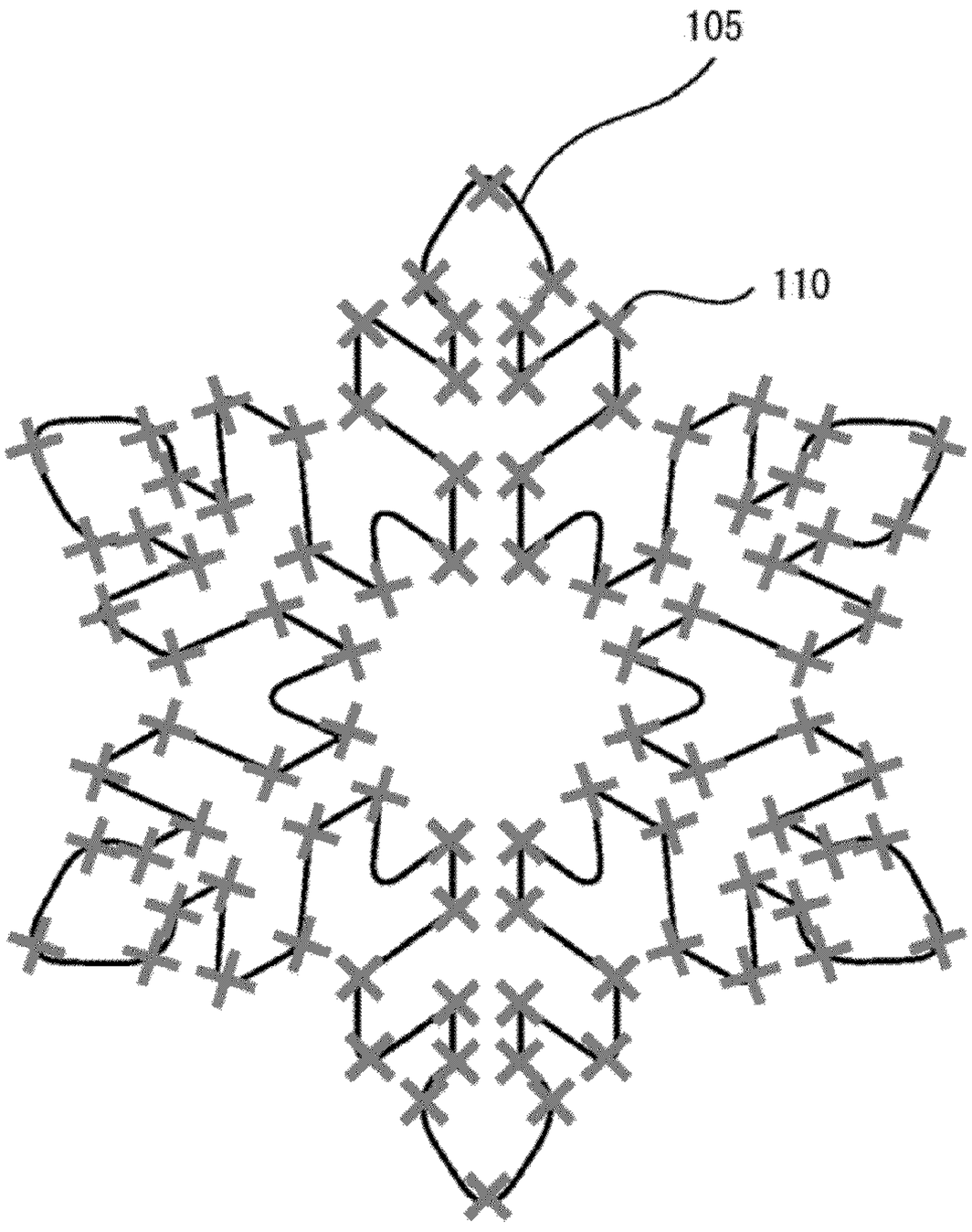


FIG. 8

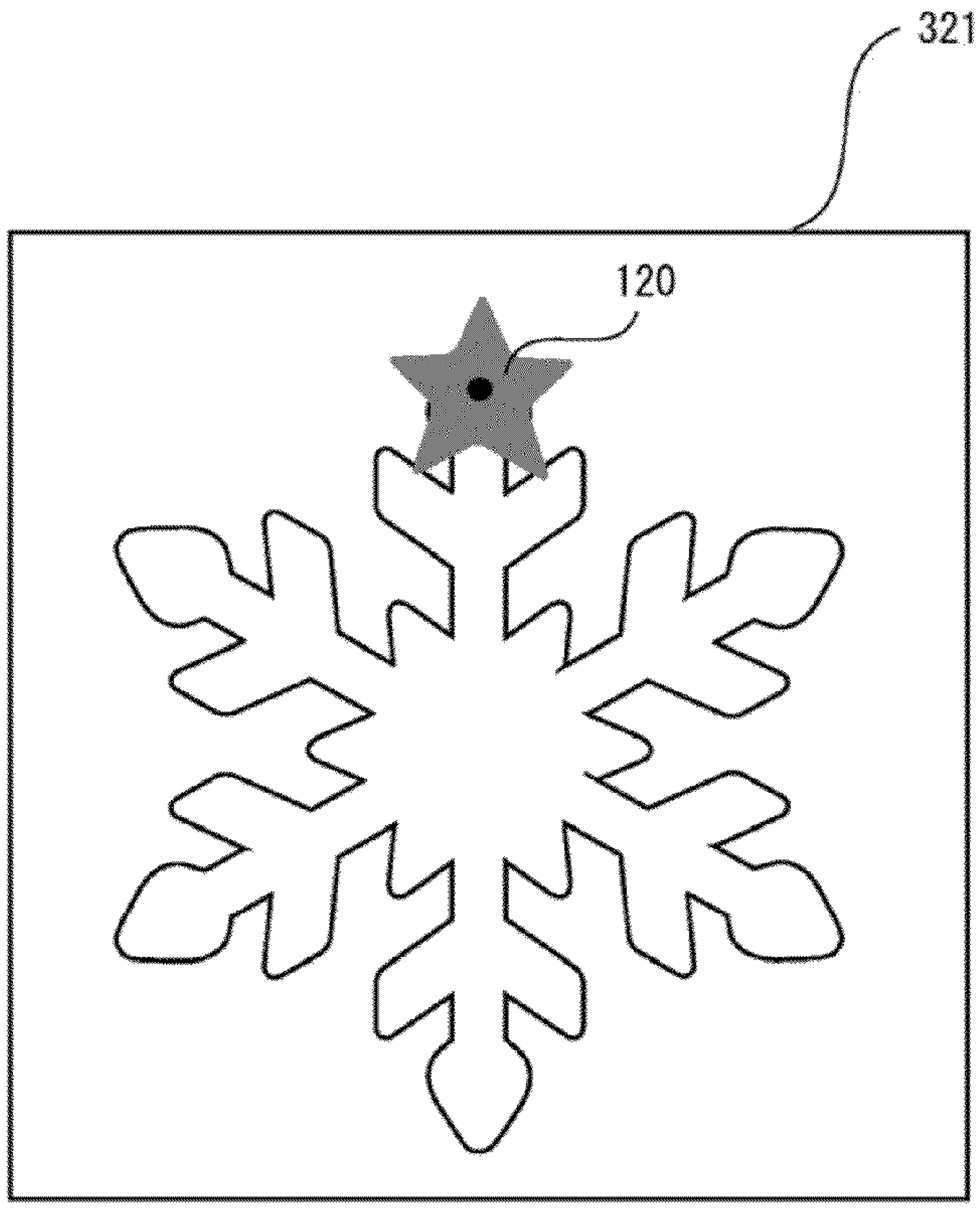


FIG. 9

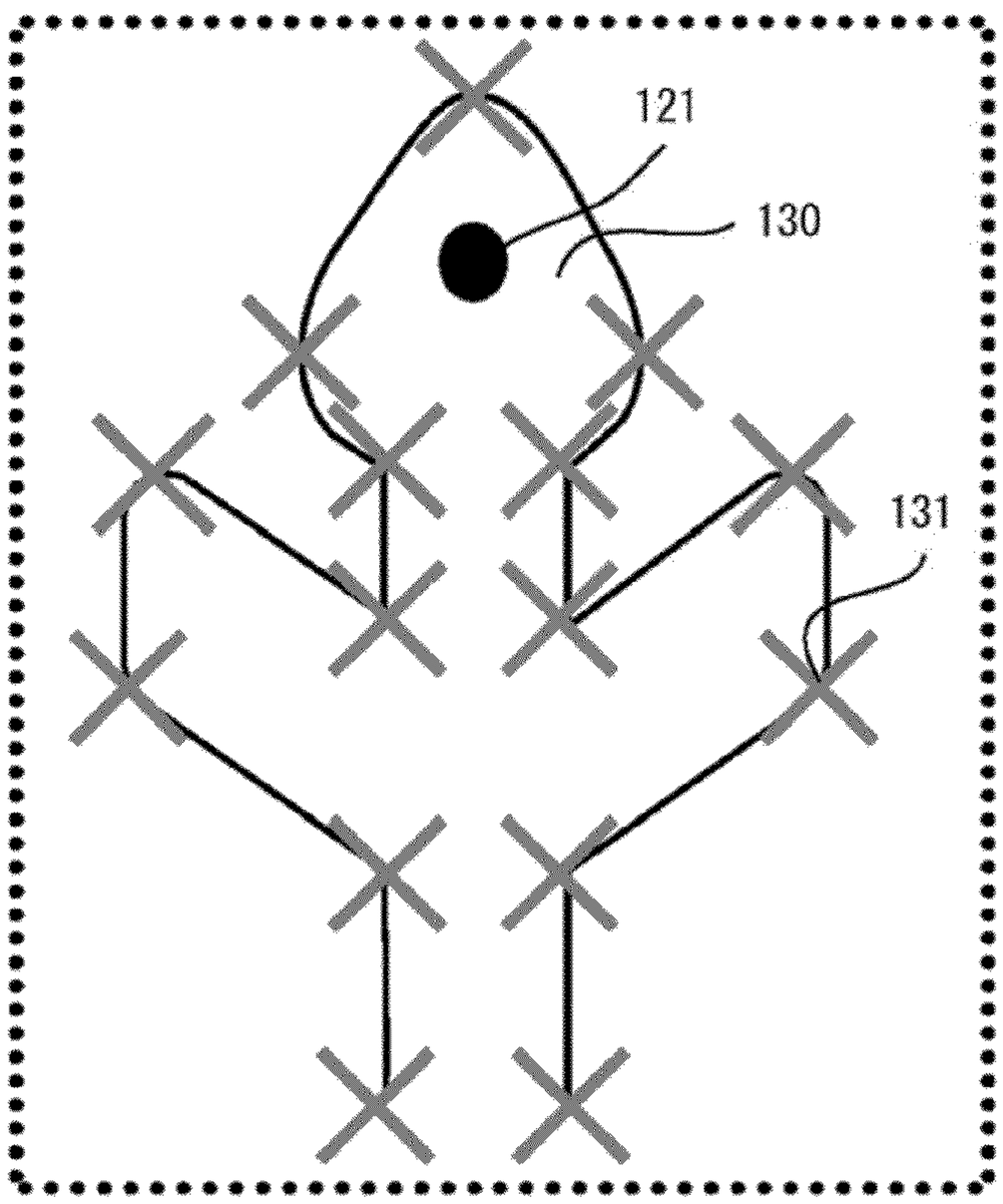


FIG. 10

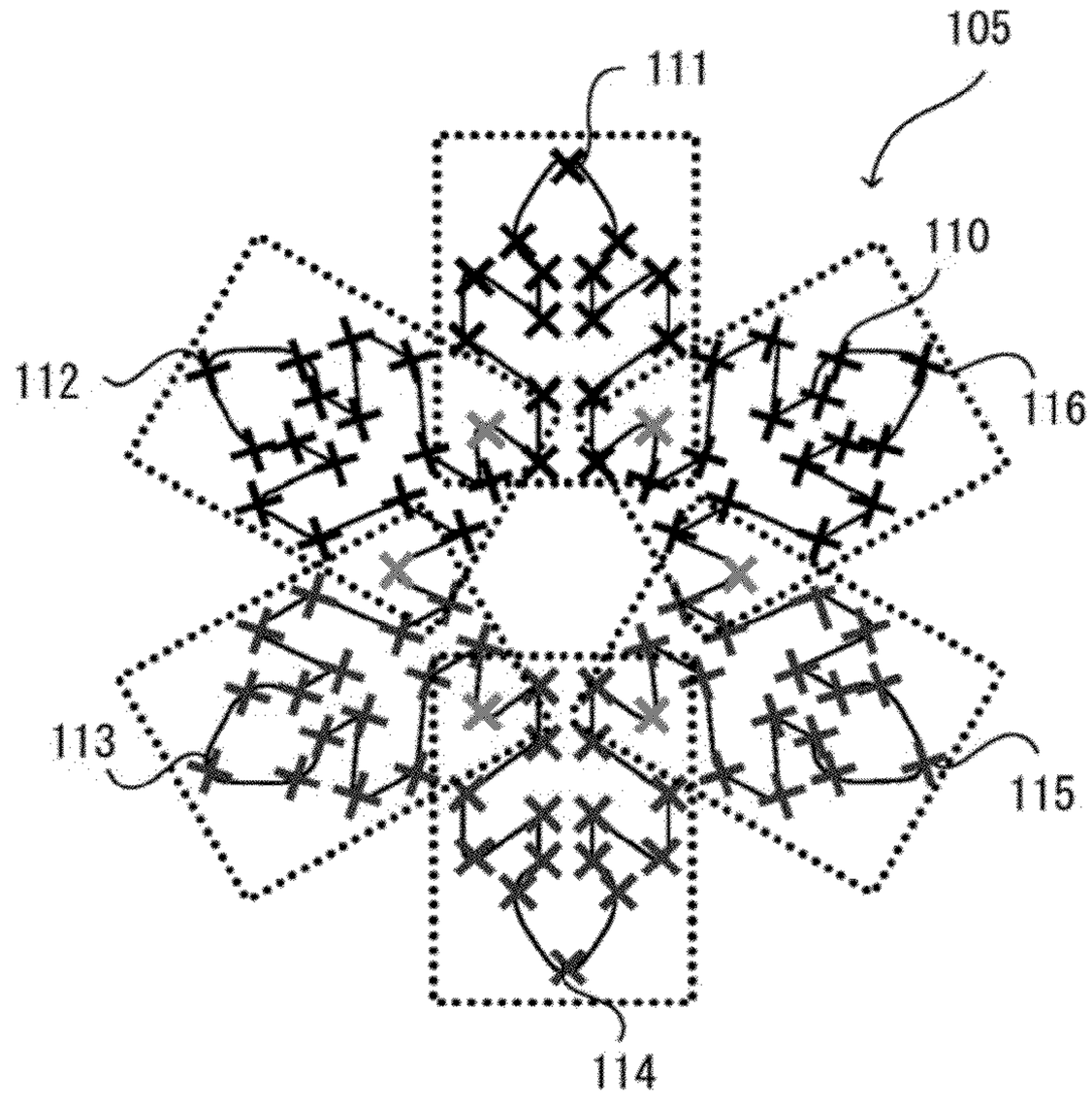


FIG. 11

310

N	ANGLE $\alpha 2$	FLAG $\beta 2$	CENTER COORDINATES 121
1	0°	0	P1 (X1, Y1)
2	60°	0	P2 (X2, Y2)
3	120°	0	P3 (X3, Y3)
4	180°	0	P4 (X4, Y4)
5	240°	0	P5 (X5, Y5)
6	300°	0	P6 (X6, Y6)

FIG. 12

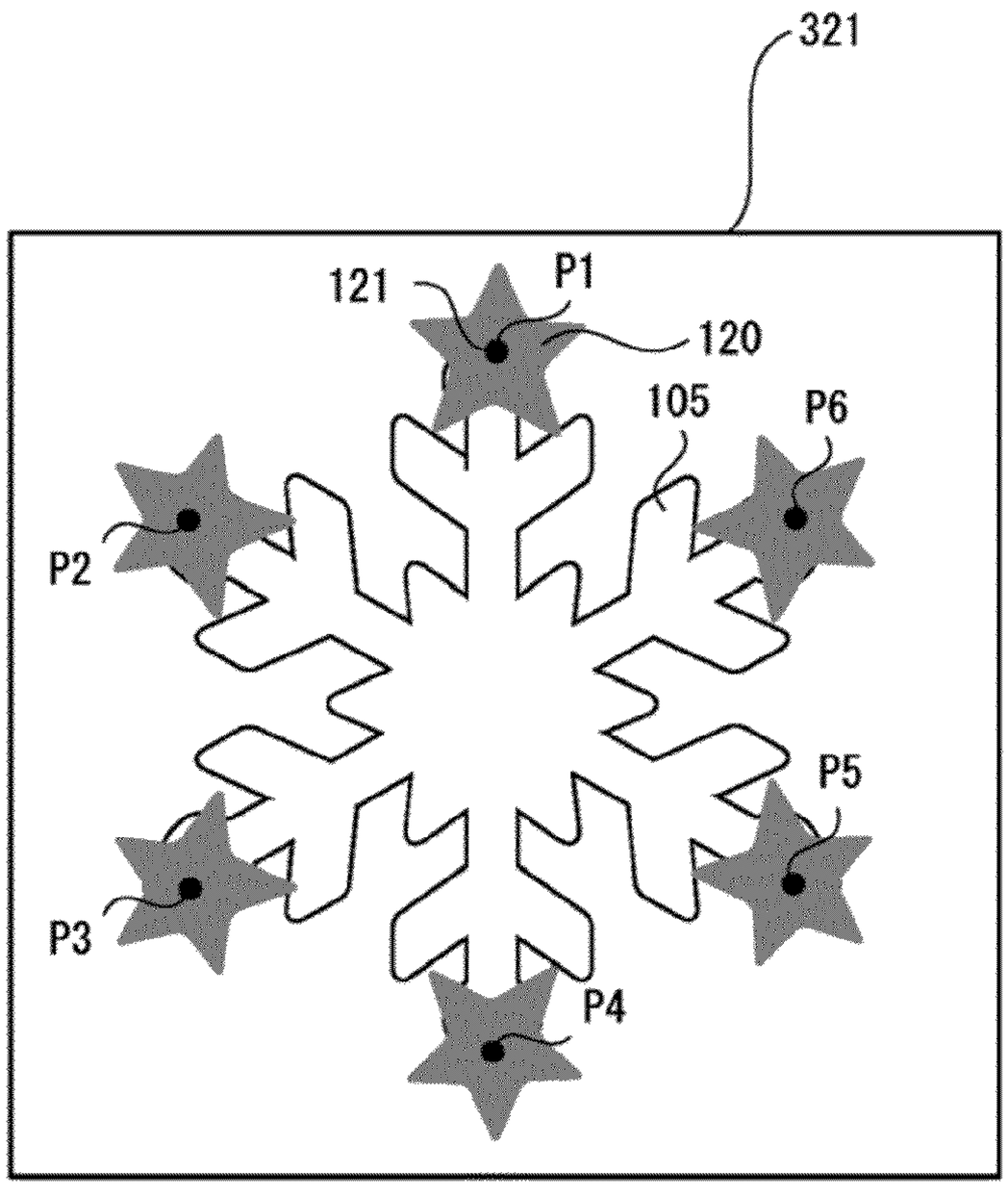
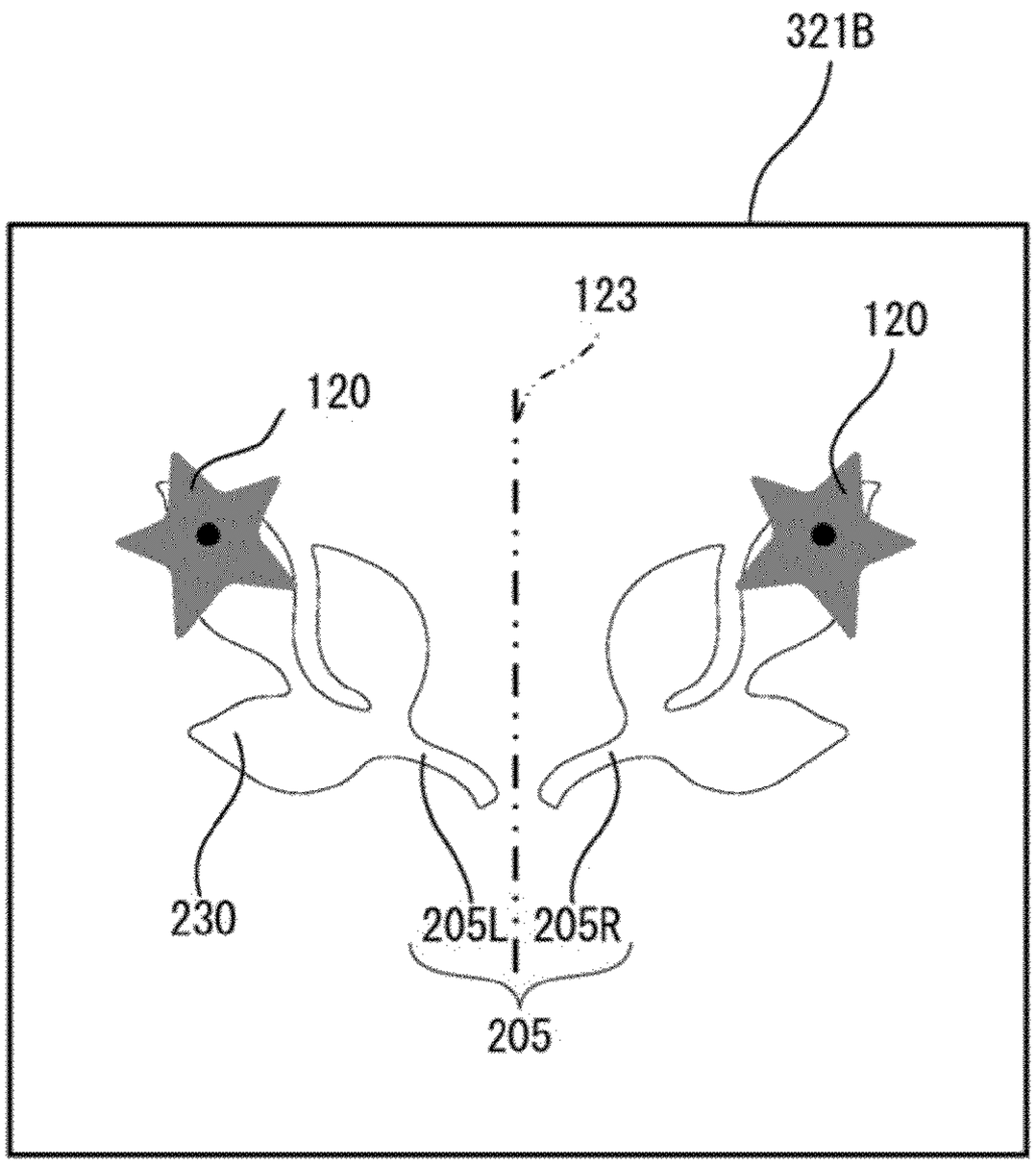


FIG. 13



SEWING MACHINE, COMPUTER-READABLE MEDIUM STORING SEWING PROGRAM, AND SEWING METHOD

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to Japanese Patent Application No. 2013-135994, filed Jun. 28, 2013. The disclosure of the foregoing application is incorporated herein by reference in its entirety.

BACKGROUND

The present disclosure relates to a sewing machine capable of sewing an embroidery pattern, a computer-readable medium storing a sewing program, and a sewing method.

In related art, a sewing machine is known that is capable of sewing an embroidery pattern.

For example, the known sewing machine is provided with a device that regularly arranges an embroidery pattern in a plurality of positions in accordance with an arrangement type that is selected from among arrangement types that have been determined in advance. The sewing machine sews the embroidery pattern in a plurality of positions on a work cloth in accordance with the selected arrangement type.

SUMMARY

When an embroidery pattern is sewn on a work cloth on which a design has been formed in advance, there are cases in which a user wants to arrange the embroidery pattern in accordance with the design. However, when a position of the embroidery pattern is set using the known sewing machine, it is necessary for the user to use a special template and to perform positioning by visual check, resulting in complicated operations.

Various embodiments of the broad principles derived herein provide a sewing machine, a computer-readable medium string a sewing program, and a sewing method that are configured to sew a plurality of embroidery patterns by automatically arranging the plurality of embroidery patterns in appropriate positions on a work cloth on which a design has been formed.

The embodiments herein provide a sewing machine that includes an image capturing portion, a sewing portion, a processor, and a memory. The image capturing portion is configured to capture an image of a design that is formed in advance on a work cloth. The sewing portion is configured to sew an embroidery pattern. The memory is configured to store computer-readable instructions, the computer-readable instructions, when executed by the processor, causing the sewing machine to perform operations including: extracting feature points of the design based on the image captured by the image capturing portion; extracting, from among the extracted feature points of the design, feature points of a unit design, the unit design being a part of the design; generating, based on the extracted feature points of the unit design, feature points of a symmetrical design, the symmetrical design being a design symmetrical to the unit design; cross-checking the extracted feature points of the design and the generated feature points of the symmetrical design; determining an arrangement of the embroidery pattern with respect to the symmetrical design, based on a result obtained by the cross-checking the feature points of the design and the feature points of the symmetrical design; and causing the sewing portion to sew the embroidery pattern based on the determined arrangement of the embroidery pattern with respect to the symmetrical design.

The embodiments described herein also provide a non-transitory computer readable medium storing a sewing program. The sewing program includes computer-readable instructions to be executed by a processor of a sewing machine. The sewing machine includes an image capturing portion and a sewing portion. The image capturing portion is configured to capture an image of a design that is formed in advance on a work cloth. The sewing portion is configured to sew an embroidery pattern. The sewing program includes computer-readable instructions to cause the processor to perform the steps of: extracting feature points of the design based on the image captured by the image capturing portion; extracting, from among the extracted feature points of the design, feature points of a unit design, the unit design being a part of the design; generating, based on the extracted feature points of the unit design, feature points of a symmetrical design, the symmetrical design being is a design symmetrical to the unit design; cross-checking the extracted feature points of the design and the generated feature points of the symmetrical design; determining an arrangement of the embroidery pattern with respect to the symmetrical design, based on a result obtained by the cross-checking the feature points of the design and the feature points of the symmetrical design; and causing the sewing portion to sew the embroidery pattern based on the determined arrangement of the embroidery pattern with respect to the symmetrical design.

The embodiments described herein also provide a sewing method that includes: extracting feature points of a design based on an image captured by an image capturing portion, the image capturing portion being configured to capture the image of the design that is formed in advance on a work cloth; extracting, from among the extracted feature points of the design, feature points of a unit design, the unit design being a part of the design; generating, based on the extracted feature points of the unit design, feature points of a symmetrical design, the symmetrical design being a design symmetrical to the unit design; cross-checking the extracted feature points of the design and the generated feature points of the symmetrical design; determining an arrangement of an embroidery pattern with respect to the symmetrical design, based on a result obtained by the cross-checking the feature points of the design and the feature points of the symmetrical design; and causing a sewing portion to sew the embroidery pattern based on the determined arrangement of the embroidery pattern with respect to the symmetrical design, the sewing portion being configured to sew an embroidery pattern.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present disclosure will be described below in detail with reference to the accompanying drawings in which:

FIG. **1** is a front view of a sewing machine;

FIG. **2** is a left side view of the sewing machine;

FIG. **3** is a block diagram showing an electrical configuration of the sewing machine;

FIG. **4** is a flowchart showing processing based on a sewing program;

FIG. **5** is a flowchart showing processing based on the sewing program, and is continued from FIG. **4**;

FIG. **6** is a diagram showing a captured image;

FIG. **7** is a diagram showing feature points of a design in the captured image;

FIG. **8** is a diagram showing an arrangement of an embroidery pattern that is added to the inside of the captured image;

FIG. **9** is a diagram showing a unit design;

FIG. **10** is a diagram showing pattern position data;

FIG. **11** is a diagram showing six groups of feature points;

FIG. **12** is a diagram showing an arrangement of embroidery patterns **120** that each correspond to a design that is symmetrical to the unit design in the captured image; and

FIG. **13** is a diagram showing an arrangement of embroidery patterns that each correspond to another design in the captured image.

DETAILED DESCRIPTION

Hereinafter, an embodiment of a sewing machine **101** that embodies the present disclosure will be explained. As shown in FIG. **1**, the sewing machine **101** is provided with a bed portion **11**, a pillar **12**, an arm portion **13** and a head portion **14**. The bed portion **11** is a base portion of the sewing machine **101**. The bed portion **11** has a flat surface on which a work cloth **100** can be placed. The pillar **12** extends from the bed portion **11**. The arm portion **13** extends from the pillar **12** such that the arm portion **13** faces the bed portion **11**.

Directions in the present embodiment are defined as follows. The direction in which the pillar **12** extends from the bed portion **11** is the upward direction, and the direction opposite to the upward direction is the downward direction. The direction in which the arm portion **13** extends from the pillar **12** is the left direction, and the direction opposite to the left direction is the right direction. The direction that is orthogonal to the left-right direction and to the up-down direction is the front-rear direction.

When an embroidery pattern is sewn using the sewing machine **101**, an embroidery frame **34** is mounted on an embroidery frame moving device **92**. The embroidery frame **34** is disposed above the bed portion **11** and the main body of the embroidery frame moving device **92**. The embroidery frame **34** holds the work cloth **100**. The embroidery frame moving device **92** is mounted to the left of the bed portion **11**. Although details will be described later, the embroidery frame moving device **92** moves the embroidery frame **34** in an X direction and a Y direction.

Although not shown in the drawings, in addition to the embroidery frame **34**, the sewing machine **101** is provided with a plurality of types of embroidery frames that are different in size and shape. The sewing machine **101** sets a sewable area within the embroidery frame, in accordance with the type of the embroidery frame mounted on the embroidery frame moving device **92**. In the explanation below, the explanation will be made using the embroidery frame **34**, for explanatory convenience. The embroidery frame **34** has a known structure in which an inner frame and an outer frame clamp and hold the work cloth **100**, and a detailed explanation of the embroidery frame **34** is omitted.

The embroidery frame moving device **92** is provided with a carriage cover **35** that extends in the front-rear direction. The carriage cover **35** is provided on an upper portion of the main body of the embroidery frame moving device **92**. A Y axis moving mechanism (not shown in the drawings) is provided inside the carriage cover **35**. The Y axis moving mechanism moves a carriage (not shown in the drawings) in a Y direction (the front-rear direction of the sewing machine **101**). The embroidery frame **34** can be mounted on and removed from the carriage. Therefore, the Y axis moving mechanism moves the embroidery frame **34** in the Y direction.

A mounting portion (not shown in the drawings) is provided to the right of the carriage. The mounting portion protrudes to the right with respect to the right side surface of the carriage cover **35**. The mounting portion mounts the embroidery frame **34**.

An X axis moving mechanism (not shown in the drawings) is provided inside the main body of the embroidery frame moving device **92**. The X axis moving mechanism moves the carriage, the Y axis moving mechanism and the carriage cover **35** in an X direction (the left-right direction of the sewing machine **101**). The embroidery frame **34** can be mounted on and removed from the carriage. Therefore, the X axis moving mechanism moves the embroidery frame **34** in the X direction.

While moving the embroidery frame **34** in the X direction and the Y direction, the sewing machine **101** drives a needle bar **6** shown in FIG. **2** and a shuttle mechanism (not shown in the drawings) that is provided inside the bed portion **11**. By doing this, a desired embroidery pattern is sewn on the work cloth **100** held by the embroidery frame **34**.

A liquid crystal display **15** is provided on the front surface of the pillar **12**. The liquid crystal display **15** has a vertically long rectangular shape. The liquid crystal display **15** displays images of various items, such as a plurality of types of patterns, command names to execute various types of functions, various types of messages and the like. A transparent touch panel **26** is provided on the front surface of the liquid crystal display **15**. A user can select a pattern to be sewn or a command to be executed, if the user touches a portion of the touch panel **26** that corresponds to the item displayed on the liquid crystal display **15**, using a finger or a special touch pen (not shown in the drawings).

A sewing start-and-stop switch **21** is provided on a lower portion of the front surface of the arm portion **13**. The sewing start-and-stop switch **21** starts or stops the sewing by the sewing machine **101**. When the sewing start-and-stop switch **21** is depressed, a command to start or stop sewing is input to a control portion **60** shown in FIG. **3**.

The needle bar **6**, a sewing needle **7**, a presser bar **45** and a presser foot **47** will be explained with reference to FIG. **2**. In FIG. **2**, for explanatory convenience, illustrations of the embroidery frame moving device **92** and the embroidery frame **34** are omitted. The needle bar **6** and the presser bar **45** are provided below the head portion **14**. The sewing needle **7** is fixed to the lower end of the needle bar **6**. The presser foot **47** is fixed to the lower end of the presser bar **45**. The presser foot **47** presses the work cloth **100**.

An image sensor **50** is provided on a front lower portion inside the head portion **14**. The image sensor **50** captures an image of the top surface of the work cloth **100**. An area inside the embroidery frame **34** that is captured by the image sensor **50** is called a capturing area. The image sensor **50** is provided with a CMOS sensor that captures images, and a control circuit that controls the CMOS sensor. The image sensor **50** is fixed to a support frame **51**. The support frame **51** is attached to a frame (not shown in the drawings) of the sewing machine **101**. A sewing portion includes the embroidery frame **34**, the embroidery frame moving device **92**, the carriage cover **35**, the X axis moving mechanism, the Y axis moving mechanism, an X axis motor **83**, a Y axis motor **84**, the needle bar **6** and the shuttle mechanism.

An electrical configuration of the sewing machine **101** will be explained with reference to FIG. **3**. The control portion **60** of the sewing machine **101** includes a CPU **61**, a ROM **62**, a RAM **63**, a card slot **17**, an external access RAM **68**, an input interface **65** and an output interface **66**, which are mutually connected by a bus **67**. The sewing start-and-stop switch **21**,

the touch panel **26** and the image sensor **50** are connected to the input interface **65**. Drive circuits **72**, **75**, **85** and **86** are connected to the output interface **66**. The drive circuit **72** drives a sewing machine motor **79**. The drive circuit **75** drives the liquid crystal display **15**. The drive circuits **85** and **86** respectively drive the X axis motor **83** and the Y axis motor **84** that move the embroidery frame **34**.

The CPU **61** performs main control of the sewing machine **101**, and performs various types of calculation and processing in accordance with program data **210** stored in the ROM **62**, which is a read-only memory unit. The ROM **62** stores the program data **210** and embroidery data **220**. The program data **210** includes a sewing program. The embroidery data **220** is data that indicates an embroidery pattern **120** shown in FIG. **8**. The embroidery pattern **120** of the present embodiment is a star-shaped pattern.

The RAM **63** is a memory unit and data can be freely read from and written into the RAM **63**. The RAM **63** stores calculation results calculated by the CPU **61**. The RAM **63** stores pattern position data **310**, captured image data **320** and relative arrangement data **330**. The captured image data **320** is data that indicates a captured image **321** that is captured by the image sensor **50**. The relative arrangement data **330** is data that indicates a relative arrangement between a position of the embroidery pattern **120** shown in FIG. **8** and feature points **131** of a unit design **130** shown in FIG. **9**.

[Sewing Program]

The sewing program will be explained with reference to FIG. **4** to FIG. **12**. The sewing program is executed by the CPU **61** of the sewing machine **101**. For example, when the user touches the touch panel **26** and selects the desired embroidery pattern **120**, the CPU **61** reads the program data **210** from the ROM **62** and executes the sewing program. Each step shown in flowcharts of FIG. **4** and FIG. **5** indicates processing of the CPU **61** that is performed based on the sewing program.

In the present embodiment, a design **105** shown in FIG. **6** is printed in advance on the work cloth **100** held by the embroidery frame **34**. The design **105** is, for example, a pattern of a snow crystal. In an embroidery coordinate system, the left-right direction of the sewing machine **101** matches the X axis direction and the front-rear direction of the sewing machine **101** matches the Y axis direction. The direction from the left to the right of the sewing machine **101** is an X axis plus direction, and the direction from the rear to the front is a Y axis plus direction.

In the present embodiment, a relative position between an origin position S of the embroidery frame **34** shown in FIG. **1** and the capturing area of the image sensor **50** is set in advance. That is, the embroidery frame **34** is located in the origin position S. The capturing area is located in front of a needle drop point of the sewing needle **7**, on the top surface of the work cloth **100**. The origin position S of the embroidery frame **34** is a position in which the central position of the sewable area set inside the embroidery frame **34** matches the needle drop point of the sewing needle **7**. The needle drop point of the sewing needle **7** is a point at which the sewing needle **7** pierces the work cloth **100** when the sewing needle **7** moves downward.

At step S**11**, the CPU **61** determines whether or not a capturing key (not shown in the drawings) displayed on the liquid crystal display **15** has been depressed. When the CPU **61** determines that the capturing key has been depressed (yes at step S**11**), the CPU **61** advances the processing to step S**12**. When the CPU **61** determines that the capturing key has not been depressed (no at step S**11**), the CPU **11** repeats the processing at step S**11**.

At step S**12**, the CPU **61** causes the image sensor **50** to capture an image of the capturing area. Specifically, the CPU **61** outputs a capturing command to the image sensor **50**. When the image sensor **50** receives the capturing command, the image sensor **50** captures the image of the capturing area inside the embroidery frame **34**. As shown in FIG. **6**, the capturing area includes the design **105** that has been formed in advance on the work cloth **100**. The CPU **61** causes the RAM **63** to store, as the captured image data **320**, the captured image **321** obtained by capturing the capturing area.

At step S**13**, as shown in FIG. **7**, the CPU **61** extracts feature points **110** of the design **105** based on the captured image **321** captured by the image sensor **50**. Although, as shown in FIG. **6**, the upper left vertex of the captured image **321** is the origin of the coordinates in the present embodiment, the origin of the coordinates may be changed as appropriate. Specifically, the CPU **61** reads the captured image data **320** from the RAM **63**. The CPU **61** extracts the feature points **110** of the design **105** by performing image processing of a known technology. The CPU **61** causes the RAM **63** to store the extracted feature points **110**. The feature points **110** are coordinates of points at which the contour line of the design **105** curves at a predetermined angle or more. In FIG. **7**, the feature points **110** are shown by points that are indicated by "X".

A method for extracting the feature points **110** will be specifically explained. First, the CPU **61** extracts straight lines from the captured image **321**. The well-known Hough transform is used to extract the straight lines. The CPU **61** performs Sobel filter processing on the captured image **321**, and generates an edge intensity image that indicates positions at which the density value of the image rapidly changes. The CPU **61** binarizes the edge intensity image and produces an edge point sequence image. The CPU **61** performs the Hough transform on the edge point sequence image, and generates a Hough transformed image. The CPU **61** performs non-maximum suppression processing on the Hough transformed image, and extracts locally bright points in the Hough transformed image. The CPU **61** performs inverse Hough transform processing on bright points, of the extracted bright points, that are brighter than a predetermined threshold value, and thus extracts the straight lines. The CPU **61** calculates intersection points of the extracted straight lines, and extracts the intersection points as the feature points **110** of the design **105**.

At step S**15**, the CPU **61** reads the embroidery data **220** from the ROM **62**.

After that, the CPU **61** extracts, from among the feature points **110** extracted at step S**13**, feature points of the unit design **130** that is a part of the design **105**. Specifically, the CPU **61** performs processing at step S**17**, step S**19** and step S**21**.

At step S**17**, as shown in FIG. **8**, the CPU **61** determines whether or not the embroidery pattern **120** has been arranged on the captured image **321** captured by the image sensor **50**. Specifically, the CPU **61** causes the liquid crystal display **15** to display the captured image **321**. The user uses a finger or a touch pen to touch a desired position of the touch panel **26** on the liquid crystal display **15** on which the captured image **321** is displayed, and thus specifies the position of the star-shaped embroidery pattern **120**. The CPU **61** detects contact of the finger or the touch pen with the touch panel **26**, and receives the specification of the position of the embroidery pattern **120**. When the position of the embroidery pattern **120** is received, the CPU **61** determines that the embroidery pattern **120** has been arranged (yes at step S**17**), and advances the processing to step S**19**. When the CPU **61** determines that the

embroidery pattern **120** has not been arranged (no at step S**17**), the CPU **61** repeats the processing at step S**17**.

At step S**19**, the CPU **61** determines center coordinates **121** of the embroidery pattern **120**. Specifically, the CPU **61** determines coordinates of a specific position of the embroidery pattern **120** as the center coordinates **121**. The specific position of the embroidery pattern **120** is, for example, the central position of mask data of the embroidery pattern **120**. The mask data is data of a smallest rectangle that contains the whole of the embroidery pattern **120**. The CPU **61** causes the RAM **63** to store the center coordinates **121** of the embroidery pattern **120**, as the pattern position data **310**.

At step S**21**, as shown in FIG. **9**, the CPU **61** extracts the feature points **131** of the unit design **130** from among the feature points **110** extracted at step S**13**. The unit design **130** is a design that is located around the center coordinates **121** determined at step S**19**. The location around the center coordinates **121** indicates feature points within a predetermined range with respect to the center coordinates **121**. The predetermined range is, for example, a rectangular area with respect to the center coordinates **121**. The predetermined range is not limited to the rectangular area, and for example, may be an area inside a circle of a radius γ whose center point is the center coordinates **121**. The radius γ may be a value that is set in advance or a value that is set by the user as appropriate. The CPU **61** causes the RAM **63** to store the extracted feature points **131**.

At step S**23**, the CPU **61** causes the RAM **63** to store, as the relative arrangement data **330**, a relative arrangement between the center coordinates **121** determined at step S**19** and the feature points **131** extracted at step S**21**. The relative arrangement between the center coordinates **121** and the feature points **131** is, for example, a relative positional relationship in terms of coordinates between the center coordinates **121** and the feature points **131**.

At step S**25**, the CPU **61** initializes an angle α1 and a flag β1. Specifically, the CPU **61** sets the angle α1 and the flag β1 to 0, respectively. The angle α1 indicates an angle by which the unit design **130** is to be rotated. The flag β1 is a flag indicating whether or not to invert the unit design **130**. If the flag β1=0, it indicates that the unit design **130** is not to be inverted. If the flag β1=1, it indicates that the unit design **130** is to be inverted.

At step S**26**, the CPU **61** generates feature points of a symmetrical design based on the feature points **131** extracted at step S**21**. The symmetrical design is a design that is symmetrical to the unit design **130**. Specifically, the CPU **61** causes the extracted feature points **131** to rotate around a given first point by a rotation angle indicated by the angle α**1**. For example, among the extracted feature points **131**, the first point may be the feature point **131** that is closest to the center coordinates **121**, or may be the feature point **131** whose X coordinate value and Y coordinate value are smallest.

When the flag β1=0, the CPU **61** does not invert the feature points **131** rotated by the angle α1. When the flag β1=1, the CPU **61** inverts the feature points **131** rotated by the angle α1, with respect to a virtual reference line that passes through a given second point. For example, the second point may be a given one of the extracted feature points **131**, or a point that is set by the user as appropriate. For example, the virtual reference line may be a line in the Y direction that passes through the second point, a line in the X direction that passes through the second point, or a line that is set by the user as appropriate.

In the present embodiment, when the flag β1=1, the CPU **61** inverts the feature points **131** of the unit design **130** in the left-right direction, with respect to the center line that extends in the up-down direction passing through the center coordinates **121**. For example, when the feature point (X0, Y0) exists, if it is inverted in the X direction (the left-right direction) with respect to the center line of X=Δ, the feature point (2Δ−X0, Y0) is obtained.

At step S**27**, as shown in FIG. **10**, the CPU **61** determines whether or not the feature points of the symmetrical design generated at step S**26** match the feature points **110** of the design **105** extracted at step S**13**. Specifically, the CPU **61** performs the above-described determination by performing image processing based on template matching or feature matching etc. of the known technology. When the CPU **61** determines that the feature points of the symmetrical design match the feature points **110** of the design **105** (yes at step S**27**), the CPU **61** advances the processing to step S**29**. When the CPU **61** determines that the feature points of the symmetrical design do not match the feature points **110** of the design **105** (no at step S**27**), the CPU **61** advances the processing to step S**37**. The above-described "match" includes an "almost match" in which an error is equal to or smaller than a predetermined threshold value.

The image processing to cross-check the feature points will be specifically explained. The CPU **61** cross-checks the feature points of the symmetrical design and the feature points **110** of the design **105**, using known image processing described in Japanese Laid-Open Patent Publication No. 62-92085, for example. In more detail, the CPU **61** calculates a coincidence rate (%) of the feature points of the symmetrical design and the feature points **110** of a part of the design **105**. When the coincidence rate is smaller than a predetermined threshold value, the CPU **61** determines that the feature points do not match. When the coincidence rate is equal to or larger than the predetermined threshold value, the CPU **61** determines that the feature points match.

The CPU **61** may cross-check the feature points of the symmetrical design and the feature points **110** of the design **105**, using known image processing described in Japanese Laid-Open Patent Publication No. 8-227459, for example. Specifically, the CPU **61** calculates a distance indicating a difference between each of the feature points of the symmetrical design and each the feature points **110** of a part of the design **105**. The CPU **61** calculates a total value by adding the distances between the respective feature points. When the total value is equal to or larger than a predetermined threshold value, the CPU **61** determines that the feature points do not match. When the total value is smaller than the predetermined threshold value, the CPU **61** determines that the feature points match. As long as the feature points can be cross-checked, another method may be used instead of the above-described methods.

At step S**29**, the CPU **61** causes the RAM **63** to store the angle α1 when it is determined at step S**27** that the feature points match, as an angle α2 of the pattern position data **310** shown in FIG. **11**. For example, the angle α2 is a direction in which the angle increases in the counterclockwise direction when feature points (first feature points **111**) of the unit design **130** that is facing upward are taken as 0 degrees, as shown in FIG. **10**.

In the present embodiment, as shown in FIG. **10**, the feature points **110** of the design **105**, for which the CPU **61** determines at step S**27** that the feature points match, are six groups of feature points. The six groups of feature points include first feature points **111**, second feature points **112**, third feature points **113**, fourth feature points **114**, fifth feature points **115** and sixth feature points **116**. The first feature points **11**I match the feature points **131** that are rotated by 0 degrees. The second feature points **112** match the feature points **131** that are rotated by 60 degrees. The third feature points **113** match

the feature points **131** that are rotated by 120 degrees. The fourth feature points **114** match the feature point **131** that are rotated by 180 degrees. The fifth feature points **115** match the feature point **131** that are rotated by 240 degrees. The sixth feature points **116** match the feature point **131** that are rotated by 300 degrees.

As shown in FIG. **11**, the pattern position data **310** is data relating to the position of the embroidery pattern **120**. Specifically, in the pattern position data **310**, the angle α2, a flag β2 and the center coordinates **121** are mutually associated with each other. In the present embodiment, six pieces of the pattern position data **310** that correspond to the six groups of feature points shown in FIG. **10** are stored in the RAM **63**. More specifically, the angles α2 of the six pieces of the pattern position data **310** are 0 degrees, 60 degrees, 120 degrees, 180 degrees, 240 degrees and 300 degrees, respectively.

At step S**31**, the CPU **61** causes the RAM **63** to store the flag β1 when it is determined at step S**27** that the feature points match, as the flag β2 of the pattern position data **310** shown in FIG. **11**. In the present embodiment, the flags β2 of the six pieces of the pattern position data **310** are all zero.

At step S**33**, the CPU **61** reads, from the RAM **63**, the relative arrangement data **330** that indicates the relative arrangement between the center coordinates **121** and the feature points **131**.

At step S**35**, the CPU **61** determines the arrangement of the embroidery pattern **120** with respect to the symmetrical design, based on the result of the cross-check at step S**27**. As shown in FIG. **12**, the CPU **61** calculates the center coordinates **121** of the embroidery pattern **120** for the symmetrical design, based on the relative arrangement data **330** read from the RAM **63**.

In more detail, based on the arrangement between the center coordinates **121** and the feature points **131** that is shown by the relative arrangement data **330**, the CPU **61** calculates coordinates corresponding to the center coordinates **121** in a case where the feature points of the symmetrical design are assumed to be the feature points **131** of the unit design **130**. In other words, the calculated coordinates are the center coordinates of the embroidery pattern **120** for the symmetrical design. The CPU **61** causes the RAM **63** to store the calculated center coordinates as the center coordinates **121** of the pattern position data **310** shown in FIG. **11**. In the present embodiment, the center coordinates **121** of the six pieces of the pattern position data **310** are coordinates P1, P2, P3, P4, P5 and P6 shown in FIG. **12**, respectively.

Further, the CPU **61** reads the pattern position data **310** from the RAM **63**. The CPU **61** determines the arrangement of the embroidery pattern **120** in accordance with the angle α2, the flag β2 and the center coordinates **121**, for each piece of the read pattern position data **310**. Specifically, in the same manner as when the feature points **131** of the unit design **130** are rotated, the CPU **61** rotates the embroidery pattern **120** by the rotation angle indicated by the angle α2 of the pattern position data **310**. When the flag **32** of the pattern position data **310** is equal to 1, the CPU **61** inverts the embroidery pattern **120** in the same manner as when the feature points **131** of the unit design **130** are inverted. After that, the CPU **61** determines coordinate positions of points that form the embroidery pattern **120** such that the center coordinates of the embroidery pattern **120** on which at least one of rotation and inversion has been performed match the center coordinates **121** of the embroidery position data **310**. The CPU **61** causes the RAM **63** to store the determined coordinate positions of the points that form the embroidery pattern **120**, as embroidery data indicating the arrangement of the embroidery pattern **120**.

At step S**37**, the CPU **61** determines whether or not the search for all the angles is completed. Specifically, the CPU **61** determines whether or not the angle α1 is equal to or larger than 360 degrees. When the CPU **61** determines that the angle α1 is equal to or larger than 360 degrees (yes at step S**37**), the CPU **61** advances the processing to step S**39**. When the CPU **61** determines that the angle α1 is smaller than 360 degrees (no at step S**37**), the CPU **61** advances the processing to step S**41**.

At step S**39**, the CPU **61** determines whether or not all the angles including an inverted state have been searched. Specifically, the CPU **61** determines whether or not the flag β1 is equal to 1. When the CPU **61** determines that the flag β1 is equal to 1 (yes at step S**39**), the CPU **61** advances the processing to step S**45**. When the CPU **61** determines that the flag β1 is not equal to 1 (no at step S**39**), the CPU **61** advances the processing to step S**43**.

At step S**41**, the CPU **61** adds 1 degree to the angle α1. After that, the CPU **61** returns the processing to step S**26**.

At step S**43**, the CPU **61** sets the flag β1 to 1. In order to search all the angles again based on the unit design **130** in an inverted state, the CPU **61** initializes the angle α1. Specifically, the CPU **61** sets the angle α1 to 0. After that, the CPU **61** returns the processing to step S**26**.

At step S**45**, the CPU **61** instructs the sewing portion to sew the embroidery pattern **120** based on the arrangement of the embroidery pattern **120** determined at step S**35** and on the relative position of the capturing area with respect to the embroidery frame **34**. The sewing portion receives the instruction, causes the embroidery frame **34** to move in the X direction and the Y direction, and sews the embroidery pattern **120** on the work cloth **100**. The meaning of "sewing" is driving the X axis motor **83** and the Y axis motor **84**, causing the embroidery frame moving device **92** to move the embroidery frame **34** in the X direction and the Y direction, and vertically reciprocating the needle bar **6** by driving the sewing machine motor **79**. The sewing portion includes the drive circuits **72**, **85** and **86**.

After step S**45** is completed, the CPU **61** ends the processing that is based on the sewing program. In the manner described above, in accordance with the arrangement of the embroidery patterns **120** shown in FIG. **12**, it is possible to sew the six embroidery patterns **120** beautifully and with a good appearance, with respect to the design **105** that has been formed (printed) in advance on the work cloth **100**.

Examples of Effects of the Present Embodiment

At step S**7**, the captured image **321** is displayed on the liquid crystal display **15**. The user specifies the position in which the embroidery pattern **120** is to be arranged, by touching the touch panel **26** on the liquid crystal display **15** on which the captured image **321** is displayed. Therefore, the user can easily arrange the embroidery pattern **120** in a desired position.

At step S**21**, the CPU **61** extracts, as the feature points **131** of the unit design **130**, the feature points of the design located around the center coordinates **121** of the embroidery pattern **120**. Therefore, the user can determine the unit design **130** that will be a target of cross checking, simply by specifying the position of the embroidery pattern **120**.

At step S**41**, the CPU **61** rotates the feature points **131** by 1 degree at a time until the feature points **131** of the unit design **130** are rotated by 360 degrees. Every time the feature points

131 are rotated by 1 degree, the CPU **61** determines at step S**27** whether or not the feature points **131** of the unit design **130** match the feature points **110** of the design **105**. It is thus possible to accurately perform determination of rotational symmetry.

At step S**43**, when the feature points **131** of the unit design **130** are rotated by 360 degrees, the CPU **61** inverts the feature points **131** of the unit design **130**. Every time the feature points **131** are rotated by 1 degree, the CPU **61** determines at step S**27** whether or not the feature points **131** of the unit design **130** match the feature points **110** of the design **105**. It is thus possible to accurately perform determination of line symmetry.

Modified Examples

The present disclosure is not limited to the above-described embodiment, and can be performed in various forms without departing from the spirit of the present disclosure.

In the present embodiment, the design **105** of the work cloth **100** is a shape having rotational symmetry. However, a design with a shape that is line-symmetric in the left-right direction, such as a design **205** shown in FIG. **13**, may be used. FIG. **13** shows a captured image **321**B of the design **205** that is captured by the image sensor **50**. The design **205** includes a left side design **205**L and a right side design **205**R. The left side design **205**L and the right side design **205**R are line-symmetric (left-right inverted) with respect to a virtual straight line **123** that extends in the Y direction.

The user arranges the embroidery pattern **120** such that it is overlapped with a part of the left side design **205**L. At step S**21**, the CPU **61** extracts feature points of a unit design **230** based on the position of the embroidery pattern **120**. In order to make the explanation simple, it is assumed that the design **205**L and the unit design **230** are the same. First, the CPU **61** repeatedly performs the processing at steps S**26**, S**27**, S**37** and S**41** without inverting the feature points of the unit design **230**, and cross-checks the feature points of the unit design **230** with feature points of the right side design **205**R. In this case, even when the angle $\alpha 1$ is rotated by 360 degrees, the feature points do not match (no at step S**27**). Therefore, the CPU **61** inverts the feature points of the unit design **230** in the left-right direction with respect to the virtual straight line **123** (yes at step S**37**, no at step S**39**, and step S**43**).

Next, the CPU **61** repeatedly performs steps S**26**, S**27**, S**37** and S**41**, and cross-checks the feature points of the inverted unit design **230**, which has been inverted in the left-right direction, with the feature points of the right side design **205**R. In this case, the CPU **61** determines that the right side design **205**R matches the unit design **230** (yes at step S**27**). The CPU **61** performs steps S**29** to S**35**, and automatically arranges the embroidery pattern **120** with respect to the right side design **205**R, based on the arrangement between the left side design **205**L and the embroidery pattern **120**. Note that the design on the work cloth **100** need not necessarily be a design with a shape that is line-symmetric in the left-right direction as described above, and may be a design with a shape that is line-symmetric in the up-down direction.

Although the lock stitch sewing machine **101** is exemplified in the present embodiment, a multi-needle sewing machine may be used.

In the sewing machine **101**, various functions are achieved by the CPU **61** executing the program data **210** stored in the ROM **62**. Note that the program data **210** is written into the ROM **62** when the sewing machine **101** is shipped from a factory. The ROM **62** is an example of a computer-readable storage device. For example, an HDD, a RAM or the like may be used as a storage device, in place of the ROM **62**. In this case, the storage device is a non-transitory storage medium. The non-transitory storage medium can retain data irrespective of the length of time during which the data is stored. The program data **210** may be saved in a storage medium, such as an external server. When the program data **210** is stored in a server, the program data **210** is downloaded from an external server or the like via a connection interface, and is stored in the sewing machine **101** as appropriate. In this case, the program data **210** is transmitted as a transmission signal to the sewing machine **101** from the external server or the like that is a non-transitory computer-readable storage medium.

In the present embodiment, the processing that extracts the feature points **110** of the design **105**, the processing that extracts the feature points **131** of the unit design **130**, the processing that cross-checks the coordinates indicating the feature points **110** of the design **105** and the coordinates indicating the feature points of a design that is symmetrical to the unit design **130**, and the processing that determines the arrangement of the embroidery pattern **120** with respect to the design that is symmetrical to the unit design **130** are achieved by software executed by the CPU **61**. However, each processing may be achieved by hardware.

The apparatus and methods described above with reference to the various embodiments are merely examples. It goes without saying that they are not confined to the depicted embodiments. While various features have been described in conjunction with the examples outlined above, various alternatives, modifications, variations, and/or improvements of those features and/or examples may be possible. Accordingly, the examples, as set forth above, are intended to be illustrative. Various changes may be made without departing from the broad spirit and scope of the underlying principles.

What is claimed is:

1. A sewing machine comprising:

an image capturing portion configured to capture an image of a design that is formed in advance on a work cloth;

a sewing portion configured to sew an embroidery pattern;

a processor; and

a memory configured to store computer-readable instructions, the computer-readable instructions, when executed by the processor, causing the sewing machine to perform operations comprising:

extracting feature points of the design based on the image captured by the image capturing portion;

extracting, from among the extracted feature points of the design, feature points of a unit design, the unit design being a part of the design;

generating, based on the extracted feature points of the unit design, feature points of a symmetrical design, the symmetrical design being a design symmetrical to the unit design;

cross-checking the extracted feature points of the design and the generated feature points of the symmetrical design;

determining an arrangement of the embroidery pattern with respect to the symmetrical design, based on a result obtained by the cross-checking the feature points of the design and the feature points of the symmetrical design; and

causing the sewing portion to sew the embroidery pattern based on the determined arrangement of the embroidery pattern with respect to the symmetrical design.

2. The sewing machine according to claim **1**,

wherein the extracting the feature points of the unit design comprises:

receiving specification of a position of the embroidery pattern on the image captured by the image capturing portion; and

extracting feature points of a part of the design as the feature points of the unit design, based on the received position of the embroidery pattern.

3. The sewing machine according to claim **2**,

wherein the extracting the feature points of the unit design based on the received position of the embroidery pattern comprises:

determining a specific position that corresponds to the received position of the embroidery pattern; and

extracting, from among the extracted feature points of the design, feature points of a part of the design located around the determined specific position, as the feature points of the unit design.

4. The sewing machine according to claim **2**,

wherein the extracting the feature points of the unit design comprises causing a storage portion to store a relative arrangement between the received position of the embroidery pattern and the extracted feature points of the unit design, after the feature points of the unit design have been extracted, and

wherein the determining the arrangement of the embroidery pattern comprises determining the arrangement of the embroidery pattern with respect to the symmetrical design, based on the relative arrangement between the position of the embroidery pattern and the feature points of the unit design, the relative arrangement being read from the storage portion.

5. The sewing machine according to claim **1**,

wherein the cross-checking the feature points of the design and the feature points of the symmetrical design comprises:

rotating the extracted feature points of the unit design by a plurality of different rotation angles; and

determining whether the rotated feature points of the unit design match a part of the extracted feature points of the design, and

wherein the determining the arrangement of the embroidery pattern comprises determining the arrangement of the embroidery pattern with respect to the symmetrical design, based on a rotation angle of the feature points of the unit design that have been determined to match a part of the feature points of the design.

6. The sewing machine according to claim **1**,

wherein the cross-checking the feature points of the design and the feature points of the symmetrical design comprises:

inverting the extracted feature points of the unit design when a predetermined condition is satisfied; and

determining whether the inverted feature points of the unit design or the feature points of the unit design that have not been inverted match a part of the extracted feature points of the design, and

wherein the determining the arrangement of the embroidery pattern comprises determining the arrangement of the embroidery pattern with respect to the symmetrical design, based on whether the feature points of the unit design that have been determined to match a part of the feature points of the design have been inverted.

7. A non-transitory computer-readable medium storing a sewing program, the sewing program comprising computer-readable instructions to be executed by a processor of a sewing machine, the sewing machine including an image capturing portion and a sewing portion, the image capturing portion being configured to capture an image of a design that is formed in advance on a work cloth, the sewing portion being configured to sew an embroidery pattern, the sewing program including computer-readable instructions to cause the processor to perform the steps of:

extracting feature points of the design based on the image captured by the image capturing portion;

extracting, from among the extracted feature points of the design, feature points of a unit design, the unit design being a part of the design;

generating, based on the extracted feature points of the unit design, feature points of a symmetrical design, the symmetrical design being is a design symmetrical to the unit design;

cross-checking the extracted feature points of the design and the generated feature points of the symmetrical design;

determining an arrangement of the embroidery pattern with respect to the symmetrical design, based on a result obtained by the cross-checking the feature points of the design and the feature points of the symmetrical design; and

causing the sewing portion to sew the embroidery pattern based on the determined arrangement of the embroidery pattern with respect to the symmetrical design.

8. The non-transitory computer-readable medium according to claim **7**,

wherein the extracting the feature points of the unit design comprises:

receiving specification of a position of the embroidery pattern on the image captured by the image capturing portion; and

extracting feature points of a part of the design as the feature points of the unit design, based on the received position of the embroidery pattern.

9. The non-transitory computer-readable medium according to claim **8**,

wherein the extracting the feature points of the unit design based on the received position of the embroidery pattern comprises:

determining a specific position that corresponds to the received position of the embroidery pattern; and

extracting, from among the extracted feature points of the design, feature points of a part of the design located around the determined specific position, as the feature points of the unit design.

10. The non-transitory computer-readable medium according to claim **8**,

wherein the extracting the feature points of the unit design comprises causing a storage portion to store a relative arrangement between the received position of the embroidery pattern and the extracted feature points of the unit design, after the feature points of the unit design have been extracted, and

wherein the determining the arrangement of the embroidery pattern comprises determining the arrangement of the embroidery pattern with respect to the symmetrical design, based on the relative arrangement between the position of the embroidery pattern and the feature points of the unit design, the relative arrangement being read from the storage portion.

11. The non-transitory computer-readable medium according to claim **7**,

wherein the cross-checking the feature points of the design and the feature points of the symmetrical design comprises:

rotating the extracted feature points of the unit design by a plurality of different rotation angles; and

determining whether the rotated feature points of the unit design match a part of the extracted feature points of the design, and

wherein the determining the arrangement of the embroidery pattern comprises determining the arrangement of the embroidery pattern with respect to the symmetrical design, based on a rotation angle of the feature points of the unit design that have been determined to match a part of the feature points of the design.

12. The non-transitory computer-readable medium according to claim **7**,

wherein the cross-checking the feature points of the design and the feature points of the symmetrical design comprises:

inverting the extracted feature points of the unit design when a predetermined condition is satisfied; and

determining whether the inverted feature points of the unit design or the feature points of the unit design that have not been inverted match a part of the extracted feature points of the design, and

wherein the determining the arrangement of the embroidery pattern comprises determining the arrangement of the embroidery pattern with respect to the symmetrical design, based on whether the feature points of the unit design that have been determined to match a part of the feature points of the design have been inverted.

13. A sewing method comprising:

extracting feature points of a design based on an image captured by an image capturing portion, the image capturing portion being configured to capture the image of the design that is formed in advance on a work cloth;

extracting, from among the extracted feature points of the design, feature points of a unit design, the unit design being a part of the design;

generating, based on the extracted feature points of the unit design, feature points of a symmetrical design, the symmetrical design being a design symmetrical to the unit design;

cross-checking the extracted feature points of the design and the generated feature points of the symmetrical design;

determining an arrangement of an embroidery pattern with respect to the symmetrical design, based on a result obtained by the cross-checking the feature points of the design and the feature points of the symmetrical design; and

causing a sewing portion to sew the embroidery pattern based on the determined arrangement of the embroidery pattern with respect to the symmetrical design, the sewing portion being configured to sew an embroidery pattern.

14. The sewing method according to claim **13**,

wherein the extracting the feature points of the unit design comprises:

receiving specification of a position of the embroidery pattern on the image captured by the image capturing portion; and

extracting feature points of a part of the design as the feature points of the unit design, based on the received position of the embroidery pattern.

15. The sewing method according to claim **14**,

wherein the extracting the feature points of the unit design based on the received position of the embroidery pattern comprises:

determining a specific position that corresponds to the received position of the embroidery pattern; and

extracting, from among the extracted feature points of the design, feature points of a part of the design located around the determined specific position, as the feature points of the unit design.

16. The sewing method according to claim **14**,

wherein the extracting the feature points of the unit design comprises causing a storage portion to store a relative arrangement between the received position of the embroidery pattern and the extracted feature points of the unit design, after the feature points of the unit design have been extracted, and

wherein the determining the arrangement of the embroidery pattern comprises determining the arrangement of the embroidery pattern with respect to the symmetrical design, based on the relative arrangement between the position of the embroidery pattern and the feature points of the unit design, the relative arrangement being read from the storage portion.

17. The sewing method according to claim **13**,

wherein the cross-checking the feature points of the design and the feature points of the symmetrical design comprises:

rotating the extracted feature points of the unit design by a plurality of different rotation angles; and

determining whether the rotated feature points of the unit design match a part of the extracted feature points of the design, and

wherein the determining the arrangement of the embroidery pattern comprises determining the arrangement of the embroidery pattern with respect to the symmetrical design, based on a rotation angle of the feature points of the unit design that have been determined to match a part of the feature points of the design.

18. The sewing method according to claim **13**,

wherein the cross-checking the feature points of the design and the feature points of the symmetrical design comprises:

inverting the extracted feature points of the unit design when a predetermined condition is satisfied; and

determining whether the inverted feature points of the unit design or the feature points of the unit design that have not been inverted match a part of the extracted feature points of the design, and

wherein the determining the arrangement of the embroidery pattern comprises determining the arrangement of the embroidery pattern with respect to the symmetrical design, based on whether the feature points of the unit design that have been determined to match a part of the feature points of the design have been inverted.

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